1.56 to 2.07. The comet was re-observed on its return in 1873 and in 1879, but has not been seen since.

Wolf's 1884 comet is also due at perihelion in April, but the conditions for its observation will be very unfavourable.

Another comet which may return towards the end of this year is the faint one discovered by Prof. Barnard in 1892. It was not seen, however, in 1899, and, as its exact period is doubtful, although probably about 6½ years, it may again escape detection.

CASTOR A QUADRUPLE STAR.—In a communication to the Astronomical Society of the Pacific (*Publication* No. 99) Prof. Campbell discusses the multiple character of Castor, and states that Dr. Curtis, using the Mills spectrograph attached to the 36-inch refractor of the Lick Observatory, recently discovered that the brighter component of the system is attended by a faint companion. The fainter component was shown by M. Belopolsky, in 1896, to be similarly double, so that in Castor we have a quadruple system in which each component of a visual double is attended by a faint companion. The period of the fainter system is about three days, but further observations of the brighter double will have to be made before its period can be determined.—(*Popular Astronomy*, No. 2, vol. xiii.)

BLOOD PRESSURES IN MAN.[1]

THE lecturer began by contrasting Galen's conception of the oscillation of the blood, about the liver as a centre, with the cardiac circulation of Harvey. The pulmonary circulation—for the purposes of this lecture—was omitted, and attention directed exclusively to that in the systemic arteries.

The physical characters of the flow of fluids were briefly described by the example of water in an open stream. A stream might well up from a spring in a flat country, and swim with very low pressure to its mouth; or, falling from a mountain, might have pressure enough to carry men and horses off their legs. If the volume were also great, as in the sea, it might exercise a pressure of many tons to the square yard, and smash great bulwarks to pieces. But in the higher animals the blood flows in closed channels, so that in such a scheme as theirs the dimensions of the channels assume a very important value. Moreover, in mammalia the circulating fluid is not water, but a thicker fluid—the blood—which (in man) has at least four times the viscosity of water. The enormous value of friction in the circulation was then considered, and it was shown that in this factor the kind of vessel wall does not signify much, as the wall is lined by a practically stationary layer of the fluid; friction, therefore, which uses up 99/100ths of the heart's power, depends on the factor of viscosity together with that of the dimension of the channels, or closed bed. It may be said that the blood pressures—that is, the arterial pressures—in man depend on viscosity and dimension of stream bed.

Now so far the closed tubes had been regarded as rigid. But if in animals the tubes were rigid the circulation would be carried on under great difficulties. For instance, there would be no accommodation; only so much blood could be driven into the system as issued at the periphery; the stream, too, would be quite intermittent, with very high maximum and very low minimum pressures, which would not serve for continuous nutrition, and by its extremes of pressures would soon wear down the arteries. For instance, in the bagpipes, were it not for the air reservoir the sound would issue in spasmodic screams; whereas the air-bag turns the intermittent blowing into a continuous feed of air. In the arterial system of man the same provision is made; its tubing is highly elastic, and a chief part of it—namely, the aorta—being relatively wider than other branches of the tree, contains, like the bagpipe reservoir, accommodation for very variable supplies of output from the heart pump. Thus a very large part of the heart power is used in dilatation of the vessels, and by these is given back to the blood. The valves of the heart serve a like purpose of regulating the pressure of the supply to the vascular system.

[1] Abstract of a lecture delivered by Prof. T. Clifford Allbutt, F.R.S., at the Royal Institution on February 3.

The lecturer in the next place dealt with the pulse, contrasting the travel of the wave with the travel of the blood itself. The wave due to the shock of the heart beat travels, ordinarily, about twenty times as fast as a given particle of the blood itself. The tenser the walls of the arteries the faster the wave travels along the taut vessels, but the slower the passage of the blood itself. Herein lies one of the chief evils of a morbid rise of arterial pressure; more stress on the vessels, less distribution of their contents. Many of these processes were illustrated by lantern slides and demonstrations by Dr. Dixon, demonstrator of pharmacology in Cambridge.

After these principles Dr. Dixon exhibited the various instruments in use for measuring blood pressures in man, and the means by which their curves may be recorded on a revolving drum (kymograph).

The lecturer then entered upon the vital properties of the arteries—that they are not only elastic, and so accommodate themselves to the varying pressures, but are endowed also with nervous governance, whereby they effect a large economy in work and material. Several functions of the human body cannot, save within small limits, work together. If we are digesting we are not apt for thought; the Alpine climber is mercifully unable to worry over affairs—his mind is put into abeyance; and so on. Thus the arterial system, by the means of its nervous connections, contracting in some areas and dilating in others, automatically diverts its fertilising streams hither or thither as needs arise. Moreover, it can enlarge or diminish its bed according to the total quantities of blood temporarily in circulation—a quantity which is very variable. By contracting the arteries in considerable areas and correspondingly dilating them in others, the fields of the various functions of the body can be used alternately, as we see in the irrigation of Alpine meadows. By the same means the very various pressures of the blood can be counteracted. When under muscular effort, for instance, the pressure is raised, a corresponding area outside the muscles is dilated, and pressure more or less equalised; thus the heart is enabled to do the most work with the least disturbance of stresses. So in a bath, cold or very hot, the crimping up of the large cutaneous areas is compensated by large dilatations in internal areas, and pressures return to the normal in two or three minutes. The chief area in which blood can be accommodated, and thus for a time put out of circulation, is a large abdominal area.

By these considerations the lecturer was led to explain why the blood in the body does not drop down into our feet and legs, and leave the brain and other vital parts. Indeed, the blood has a strong disposition thus to obey the action of gravitation, and one of the events of approaching death is the falling of the blood into lower parts of the body, deserting the heart and brain. Obviously this is especially the case in upright animals, as in man chiefly, and in apes in some measure. It is by the vigilance of the nervous governance that the blood is held up, by the contraction of the abdominal vascular fields; and it is the failure of these mechanisms which appears as shock, syncope, or collapse. The lecturer, assisted by demonstrations by Dr. Dixon, illustrated these dispositions, citing especially the researches of Prof Leonard Hill on the distribution of the blood in various positions of the body. He also referred to the bearing of these principles on the researches of Prof. Waller and others on the dangers of anæsthetics. By some most interesting experiments by Dr. Cushing he showed how enormously the arterial pressures may be raised in case of danger of failure of supply of blood against gravity when, as in apoplexy or a depressed fracture of the skull, the blood-vessels, in the parts of the brain where all these mechanisms find their centres, are compressed and thus more or less liable to be emptied.

In the last part of the lecture the lecturer apologised for occupying time with so much physiology, in which subject he is not an investigator. But it was necessary to make manifest to his audience how great is the importance of the integrity of the arteries themselves, and of their nervous governance in function, an integrity which is a matter of life and death; for if the circulation fails in the nervous centres or heart, life must cease. Now the arteries are subject to many injurious conditions, as of certain poisons and infec-

tions, or of hard muscular labour; there are also the unexplained deteriorations of age. His personal investigations had been into the effects on the arteries of gradual increases of blood pressure. Normally, arterial pressures, as taken in the arm, rise somewhat from childhood to age—say from 80–90 mm. Hg. to 140° or perhaps 150°. These upper limits are not inconsistent with health at the age of three score, though no doubt they signify some loss of mechanical efficiency. A demonstration was given by Dr. Dixon of the difference in vascular efficiency under muscular effort between a young and an elderly man. Into the effect of certain poisons and infections on the arteries he could not enter. Senile degenerations of the arteries are not essentially allied to rise of blood pressure, though in such subjects, as in others, high pressures may arise, and must be, of course, the more dangerous. Still, senile arterial degeneration is compatible with very long life, even if with diminution of function, as the vessels silt up rather than burst.

The lecturer's own observations, now extended over many years, had been upon rise of pressure in middle life beyond, often very far beyond, that which he had regarded as normal for elderly persons. The reasons of this morbid tendency cannot yet be given, but fortunately, by medicinal and dietetic means, it can be abated, and in early stages abolished. If permitted to persist, and it is not rarely consistent with fair general health or but vague indisposition, it slowly ruins the vascular system by overstretching it. It is in such persons that the arteries may break, as in apoplexy, a catastrophe which, by timely precautions, can be prevented. The lecturer strongly urged upon all persons of middle and advancing years to have their arterial pressures tested by their physicians every four or five years, so that any disposition to excessive pressures may be averted and the integrity of the arterial tree preserved.

RADIATION PRESSURE.[1]

A HUNDRED years ago, when the corpuscular theory held almost universal sway, it would have been easier to explain the pressure of light than it is to-day, when it is certain that light is a form of wave-motion. The means at the disposal of early experimenters were inadequate to detect so small a quantity; but if the eighteenth century philosophers had been able to carry out the experiments of Lebedeff and of Nichols and Hull, and had they further known of the emission of corpuscles revealed to us by the kathode stream and by radio-active bodies, there can be little doubt that Young and Fresnel would have had much greater difficulty in dethroning the corpuscular theory and setting up the wave theory in its place. The existence of pressure due to waves, though held by Euler, seems to have dropped out of sight until Maxwell, in 1872, predicted its existence as a consequence of his electromagnetic theory of light. The first suggestion that it is a general property of waves is probably due to Mr. S. T. Preston, who in 1876 pointed out the analogy of the energy-carrying power of a beam of light with the mechanical carriage by belting, and calculated the pressure exerted on the surface of the sun by the issuing radiation. It seems possible that in all cases of energy transfer, momentum, in the direction of transfer, is also passed on and that there is, therefore, a back pressure on the source. Though there is as yet no general and direct dynamical theorem accounting for radiation pressure, Prof. Larmor has given a simple indirect mode of proving the existence of the pressure which applies to all waves in which the average energy density for a given amplitude is inversely as the square of the wave-length. He has shown that when a train of waves is incident normally on a perfectly reflecting surface, the pressure on the surface is equal to $E(1+2u/U)$, where $E/2$ is the energy density just outside the reflector in the incident train, U is the wave-velocity, and u the velocity of the reflector, supposed small in comparison with U. In a similar manner it can be shown that there is a pressure on the source, increased when the source is moving forward, decreased when it is receding. It is essential, however, that we should be able to move the reflecting surface without disturbing the medium except by reflecting the waves.

[1] Address delivered before the Physical Society on February 10 by Prof. J. H. Poynting, F.R.S., president of the society.

Though Larmor's proof is quite convincing, it is interesting to realise the way in which the pressure is produced in the different types of wave-motion. In the case of electromagnetic waves, Maxwell's original mode of treatment is the simplest. A train of waves is regarded as a system of electric and magnetic tubes transverse to the direction of propagation, each kind pressing out sideways, that is, in the direction of propagation. They press against the source from which they issue, against each other as they travel, and against any surface on which they fall. In sound-waves there is a node at the reflecting surface. If the variation of pressure from the undisturbed value were exactly proportional to the displacement of a parallel layer near the surface, and if the displacement were exactly harmonic, then the average pressure would be equal to the normal undisturbed value. But consider a layer of air quite close to the surface. If it moves up a distance, y, towards the surface, the pressure is increased. If it moves an equal distance, y, away from the surface, the pressure is decreased, but to a slightly smaller extent. The excess of pressure during the compression half is greater than its defect during the extension half, and the net result is an average excess of pressure on the reflecting surface. Lord Rayleigh, using Boyle's law, has shown that this average excess should be equal to the average density of the energy just outside the reflecting surface. In the case of transverse waves in an elastic solid, it can be shown that there is a small pressure perpendicular to the planes of shear, that is, in the direction of propagation, and that this small pressure is just equal to the energy density of the waves. The experimental verification of the pressure of elastic solid waves has not yet been accomplished, but the pressure due to sound-waves has been demonstrated by Altberg, working in Lebedeff's laboratory at Moscow, the pressure obtained sometimes rising to as much as 0.24 dyne per sq. cm. By means of a telephone manometer it was found that through a large range the pressure exerted on a surface was proportional to the intensity of the sound.

Both theory and experiment justify the conclusion that when a source is pouring out waves, it is pouring out with them forward momentum which is manifested in the back pressure against the source and in the forward pressure when the waves reach an opposing surface, and which, in the meanwhile, must be regarded as travelling with the train. It was shown that this idea of momentum in a wave-train enables us to see the nature of the action of a beam of light on a surface where it is reflected, absorbed, or refracted without any further appeal to the theory of the wave-motion of which we suppose the light to consist. In the case of total reflection there is a normal force upon the surface, in the case of total absorption there is a force normal to the surface and a tangential force parallel to the surface; while in the case of total refraction there is a normal force which may be regarded as a pull upon the surface or a pressure from within. In any real refraction there will be reflection as well, but with unpolarised light, in the case of glass, a calculation shows that the refraction-pull is always greater than the reflection-push, even at grazing incidence. An experiment, made by the president in conjunction with Dr. Barlow, was described to serve as an illustration of the idea of a beam of light being regarded as a stream of momentum. A rectangular block of glass was suspended by a quartz fibre so that the long axis of the block was horizontal. It was hung in an exhausted case with glass windows, and a horizontal beam of light was directed on to one end of the block so that it entered centrally and emerged centrally from the other end after two internal reflections. Thus a stream of momentum was shifted parallel to itself, or in this particular case a counter-clockwise couple acted on the beam. By suitable means the clockwise couple on the block, due to the pressures at the two internal reflections, was distinctly observed and approximately measured. The result obtained was of the same order as that deduced from the measurement of the energy of the beam by means of a blackened silver disc.

The extreme minuteness of these light forces appears to put them beyond consideration in terrestrial affairs, but in the solar system, where they have freer play, and vast times to work in, their effects may mount up into importance. On the larger bodies the force of the light of the sun is small compared with the gravitational attraction, but as the ratio of the radiation pressure to the gravitation pull varies in-